GRAIN INSECTS AND THEIR CONTROL

BULLETIN NO. 75
SOUTHERN COOPERATIVE SERIES
January, 1962

Agricultural Experiment Stations of North Carolina, South Carolina and Virginia, and the Agricultural Marketing Service, United States Department of Agriculture.

STORED GRAIN INSECTS AND THEIR CONTROL

IN THE MIDDLE ATLANTIC STATES

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Stored Grain Insects and Their Control in Middle Atlantic States

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It has been estimated that grain losses, due to insects and rodents amount to 250 million dollars annually. Insect damage alone accounts for approximately 200 million dollars. This tremendous loss could be drastically cut by following recommended practices of pre-harvest bin spraying, sanitation in and around storage areas, and chemical control of stored grain insects.

The Food and Drug Administration seizes thousands of pounds of grain each year and declares it contaminated and unfit for human consumption. Contamination may be due to insects, insect fragments, mouse or rat pellets, bird and chicken droppings, fungicides, and excess insecticides.

If grain is allowed to become heavily infested with insects, fumigants will kill the insects present but fragments of immature insects and adults within the kernels will remain. Cereal or other products milled from this grain will be contaminated with insect fragments and insect excreta. A program should be followed, having as its goal the prevention of insect buildup.

To prevent monetary losses and to insure the consumer of a milled product that is free of contamination farmers, grain handlers, and millers should all work toward keeping grain clean.

Grain is subject to insect injury and contamination from the time it approaches maturity in the field until final consumption. This bulletin describes some of the more important stored grain insects, their damage to grain, and the means of preventing this damage by sanitation and chemical control of insects.

Some Important Insects of Stored Grain

Insects attacking stored grain can be divided, according to their method of damaging grain, into primary grain feeders and secondary grain feeders.

Primary grain insects include those capable of attacking whole, sound kernels. Some of the insects in this group spend their immature stages within the grain kernel—only adults are seen crawling through and over the grain. Another group of primary insects live and develop outside the kernel but move from kernel to kernel and devour the grain germ or embryo. Insects capable of attacking undamaged kernels include moths, weevils, lesser grain borer, and cadelle.

Secondary grain feeders do not attack whole, undamaged kernels. They feed on insect-damaged kernels, broken kernels, particles of grain, and grain dust cast out by primary insects. Some of the insects in this group also feed on molds and fungi that develop in moist grain. This group of insects is known as bran beetles.

The United States Department of Agriculture, Agricultural Marketing Service, Marketing Research Division, Stored-Products Insects Section, provided funds for this research under contract No. 12-25-010-470.

Moths

The **Angoumois grain moth** *(Sitotroga cerealella* (Oliv.)) (fig. 1) is a straw colored insect measuring slightly less than one-quarter of an inch with its wings at rest. The adult often flies to ripening grain in the field and lays its eggs on the heads. This insect can be brought into storage from the field as eggs or young worms. In fact, approximately 50 per cent of the samples of field wheat examined were infested with this moth. The moth may also lay eggs on threshed grain in the bin. The larvae or worms bore into the kernels, which they hollow out by their feeding. After transforming into an adult or moth, they leave the inside of the kernel through a small circular hole. Only adults are seen as they fly above the grain or rest on the grain surface or bin wall.

Since the moths are rather fragile and not capable of penetrating the grain mass, they lay eggs only in the top few inches of the grain surface. Damage to grain in a bin is thus restricted primarily to the surface layer.

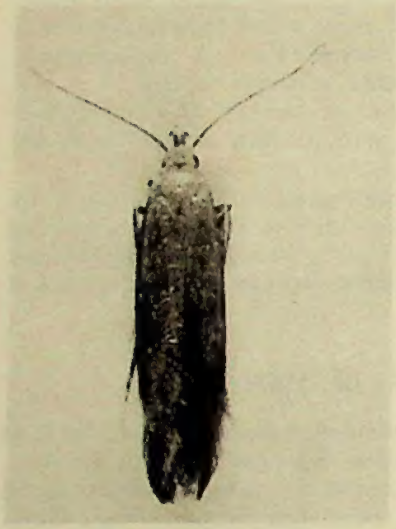

Figure 1. The Angoumois grain moth

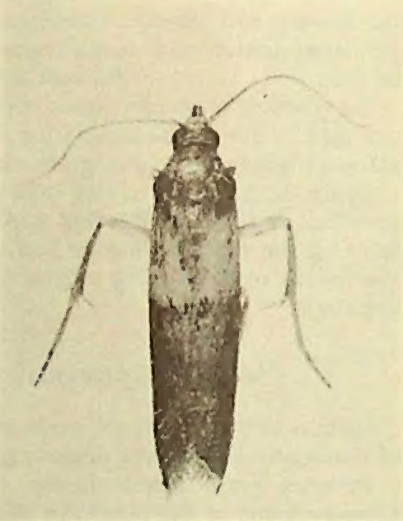

Figure 2. The Indian-meal moth

The **Indian-meal moth** *(Plodia interpunctella* (Hbn.)) (fig. 2) is five-sixteenths of an inch long with its wings at rest. When seen at rest, the front half of the wings is white or silver and the back half is brownish copper. Like the Angoumois grain moth, this insect also may attack grain in the field and be brought into storage at harvest.

All life stages (egg, larva, pupa, and adult) occur outside of the grain kernel. This insect also is destructive only in the larval stage where the worm crawls from kernel to kernel and devours the grain embryo or germ. Their presence is often detected by their characteristic webbing together of five or six kernels of wheat.

Weevils

The **rice weevil** *(Sitophilus oryza* (L.) (fig. 3) measures slightly more than one-eighth of an inch in length. Its color varies from black to reddish brown with four copper colored spots on the wing covers. This weevil lays its eggs inside the kernels of grain. The immature stages feed and live inside the kernel until they emerge as adults.

Unlike the moths, this insect is destructive as a larva and adult. The weevil is one of the best known and one of the most destructive insects that attack stored grain. They may pass from egg to adult in less than a month. It usually does not attack wheat in the field but readily attacks field corn.

The **granary weevil** *(sitophilus granarius* (L.) (fig. 4) is approximately the same size as the rice weevil. This black to brownish-black weevil lacks wings and has no spots on the wing covers. The granary weevil is more frequently found at mills or in the cooler areas of the Middle Atlantic States.

Figure 3. The rice weevil

Figure 4. The granary weevil

The **lesser rice weevil** *(Sitophilus sasakii* (Takahashi) (fig. 5) is similar to the rice weevil in appearance, life cycle, and damage. It is smaller, however, and measures less than one-eighth of an inch in length. This insect is light reddish brown in color with spots on the outer wings that are less distinct and often merged. It has a reproduction rate on wheat that surpasses that of the rice weevil.

In the Middle Atlantic States, this small form of rice weevil has been reported only in North Carolina.

Figure 5. The lesser rice weevil

Grain Borer

The **lesser grain borer** *(Rhizopertha dominica* (F.)) (fig. 6) is a dark brown, bullet-shaped insect that measures about one-eighth of an inch in length. This insect appears sluggish but it is a voracious feeder. Both the larvae and adults damage grain. Like the weevils, they will devour a kernel until only a shell is left.

Figure 6. The lesser grain borer

Grain Beetle

The **cadelle** *(Tenebroides mauritanicus* (L.)) (fig. 7) is a flattened, black beetle that measures almost one-half an inch long. Cadelles may live as long as two years. They feed on grain as larvae and adults. The cadelle usually attacks the grain germ or embryo. The larva may also cause damage by boring into the floor and walls of wooden bins. In addition to the physical damage, the abandoned holes contain reservoirs of grain and grain dust that harbor smaller insects. Approximately 90 per cent of the cadelles were collected in wooden bins.

Figure 7. The cadelle adult and larva

Bran Beetles

This group of rather small insects is comprised of some of the most abundant insects of stored grain. Although their damage can not be compared with that caused by the weevils, they may cause heating, spoilage, and contamination of stored grain and milled products.

The **saw-toothed grain beetle** *(Oryzaephilus surinamensis* (L.)) (fig. 8) is a flat, brown bettle about one-eighth of an inch long. It can be recognized by the saw-like projections on its thorax. This is one of the most active and most abundant insects in stored wheat.

The **red flour beetle** *(Tribolium castaneum (Hbst.))* (fig. 9) is slightly less than one-quarter of an inch long. It is reddish brown in color with constricted, knobbed antennae or feelers. This beetle is primarily a pest of milled grain but it is often found in stored grain.

The **confused flour beetle** *(Tribolium confusum* (Duv.) is dark reddish-brown and measures slightly less than one-quarter inch long. The antennae, though knobbed, have terminal segments which increase in size gradually rather than abruptly like those of the red flour beetle. This insect is less common in the Middle Atlantic States than the red flour beetle.

Figure 8. The saw-toothed grain beetle

Figure 9. The red flour beetle

The **flat grain beetle** *(Cryptolestes pusillus* (Schonherr)) (fig. 10) is a flat reddish brown insect which measures one-sixteenth of an inch long. Aside from its very small size, it may be recognized by the long antennae on its head. They are as long as the insect's body.

Figure 10. The flat grain beetle

The **foreign grain beetle** *(Ahasverus advena* (Walt.)) (fig. 11) is only slightly longer than the flat grain beetle. It measures approximately one-sixteenth of an inch in length. The forward end of the thorax has a small pointed projection on each side. This beetle is more commonly found in moist, moldy grain.

The **hairy fungus beetle** *(Typhaea stercorea* (L.)) (fig. 12) is an oval-shaped, brownish insect whose body is covered with minute hairs. It is approximately one-eighth of an inch long. As the name indicates, it feeds on damp, rotting, and out-of-condition grain. This insect is often seen crawling around the doors of storage bins where spilled grain is exposed to the weather.

The **khapra beetle** *(Trogoderma granarium* (Everts)) is presently confined to areas of California and Arizona. To prevent the spread of this serious pest of stored grain, a Federal quarantine has been evoked.

The adult measures less than one-eighth of an inch long. The color varies from light red-brown to dark brown. It is clothed with minute hairs and possesses indistinct red-brown markings on the wing covers. The yellow to yellow-brown larvae have tufts of hair over the body. The larvae range from one-sixteenth to one-sixth of an inch in length. Larvae have the habit of crowding into crevices in bins. Watch for this insect in your grain or milled products.

Figure 11. The foreign grain beetle

Figure 12. The hairy fungus beetle

Abundance of Stored Grain Insects

The abundance of insects in stored grain was determined by samples collected from mills, wooden farm bins, metal farm bins, and bagged wheat in granaries. The saw-toothed grain beetle was the most abundant insect collected in 1958 and 1959. Other insects of numerical importance were the rice weevil, cadelle, foreign grain beetle, and hairy fungus beetle. The relative abundance of the more important species is shown in table 1.

Table 1. Relative abundance of insects in stored wheat.

Insect	Per cent of total 1958	1959
Angoumois grain moth	1.9	5.5
Indian-meal moth	1.6	.9
Rice weevil	18.8	5.3
Granary weevil	.1	.1
Lesser grain borer	3.5	.5
Cadelle	9.2	6.2
Saw-toothed grain beetle	28.3	60.2
Red flour beetle	1.6	.9
Flat grain beetle	5.0	4.2
Foreign grain beetle	13.1	6.5
Hairy fungus beetle	3.9	7.9
Total insects collected	9329	5995

Sources of Insect Infestation

Field Infestation

Wheat is subject to infestation in the field by several moths. These insects fly from nearby storage areas and lay their eggs on the maturing heads of grain. Figure 13 shows exit holes left by the Angoumois grain moth in a head of wheat.

Corn in addition to infestation by moths, may also be infested in the field by rice weevils and several species of bran beetles.

Poor Sanitation in the Bin

Small quantities of grain left in the bin from the previous storage season may harbor enormous numbers of insects (fig. 14). If these insects are not destroyed, a serious infestation can develop in the new grain crop within a month.

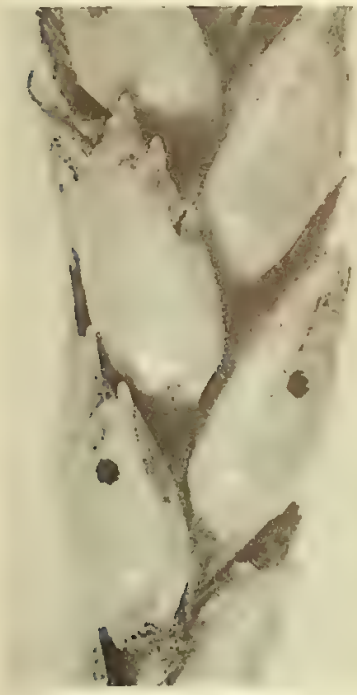

Figure 13. Exit holes left by the Angoumois grain moth in a head of wheat.

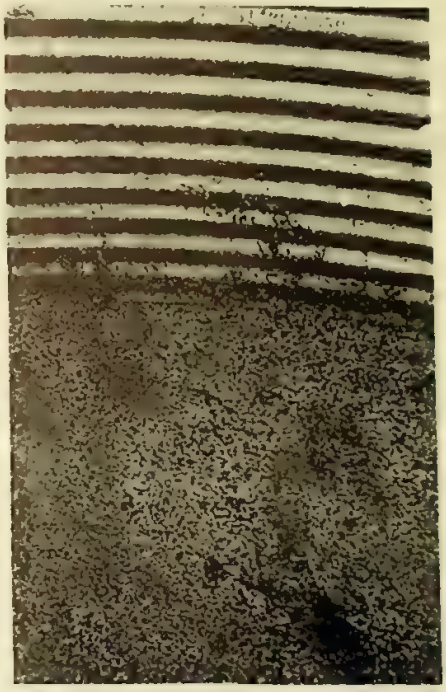

Figure 14. A small quantity of infested grain left in the bin at harvest can cause a serious early insect infestation in the new crop.

Poor Sanitation in the Vicinity of the Bin

Sanitation in the bin vicinity is also important. Insects may crawl or fly into the new grain from old grain spilled on the floor or from old stocks of infested grain nearby (figs. 15 and 16). Such reservoirs of grain may serve as a constant source of insect infestation.

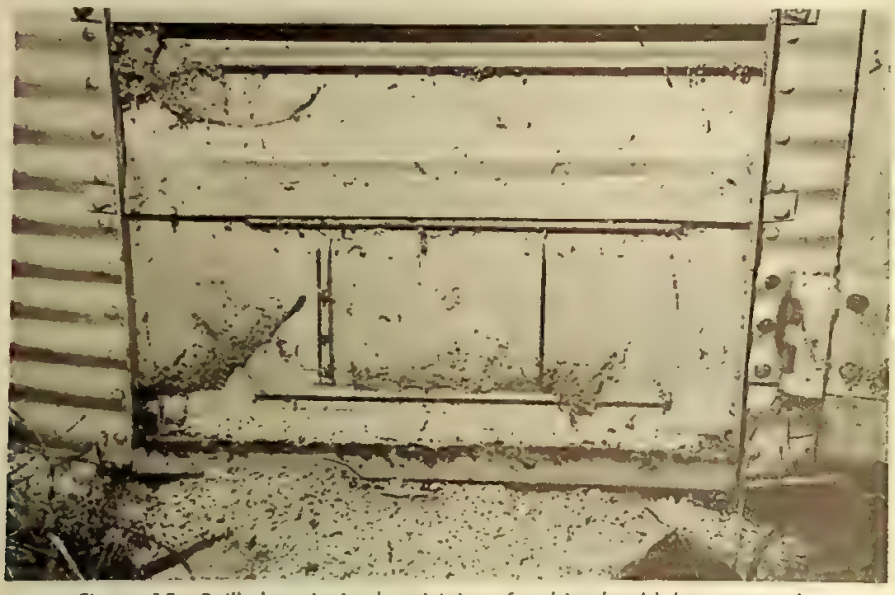

Figure 15. Spilled grain in the vicinity of a bin should be removed.

Figure 16. Infested corn (shown on the right) should be removed or fumigated.

Old Grain Bags

Many farmers harvest their wheat in bags and either store the grain in these bags or dump it into bins. These bags may be contaminated with insects if they previously contained grain (fig. 17).

Fig. 17. Old grain bags may contain refuse and insects.

Factors Affecting Insect Abundance in Stored Grain

Aside from the fact that each insect species has its own reproductive potential, there are several other factors that influence the buildup of insects in stored grain.

Grain Moisture

It is a well known fact that high moisture will affect grain quality and grade. Moisture will also affect buildup of insects. They increase more rapidly in moist grain than in dry grain. To prevent spoilage and downgrading of grain and rapid development of insects, only dry grain should be stored. Grain moisture in storage bins can be lowered by turning the grain or by using aerating fans.

Grain Temperature

Insects develop more rapidly at high temperature than at low temperature. The metabolic activity of insects may actually cause a sharp rise in the grain temperature. By their activity, insects create more favorable conditions for their development.

Insects cease laying eggs when the grain temperature drops below 65°F. Most adult insects are killed if the temperature drops below 35°F. for two weeks or below 55°F. for one month. Temperatures are low enough during the winter months in the Middle Atlantic States for cessation of reproduction in unheated bins. Many adults are also killed during periods of prolonged low temperatures that often occur in this area. If grain is dry and insect free at the approach of cold weather, you can usually depend upon it remaining in good condition until spring.

Dockage and Insect Damaged Kernels

Improperly adjusted combines may crack many kernels. This dockage or cracked grain provides an ideal situation for the rapid buildup of bran beetles. The greater the quantity of dockage, the greater the supply of food for bran insects, and the more rapid is their buildup.

Grain with a high percentage of insect-damaged kernels supports a higher population of bran beetles than clean grain free of insect-damaged kernels.

How Insects Affect Grain Quality and Grade

1. There is a loss in weight and food value of insect damaged grain.
2. Insects may cause an increase in grain moisture, resulting in caking of grain, sprouting, a musty smell, and tough grain.
3. Several species of insects eat the grain germ. This results in a decrease in the per cent germination.
4. A government loan can not be secured on grain that is graded "weevily." If an approximately 1,000 gram (1 1/8 to 1 1/4 quarts) sample contains the following insects, it will be graded "weevily":

Wheat and Rye

(a) More than one live weevil.

(b) One live weevil and any other insect injurious to stored grain.

(c) No live weevils but five other insects (bran beetles).
(d) Considerable number of live Angoumois moths or other moths are present in or on the grain.

Corn, Oats, Grain Sorghum and Mixed Grain

(a) More than one live weevil.
(b) One live weevil and five or more other insects injurious to stored grain.
(c) No live weevils but 15 other insects (bran beetles).
(d) Considerable number of live Angoumois moths or other moths are present in or on the grain.

5. Ultimate result of insects and their activity is a down-grading of grain and a lower profit.

Grain Storage Facilities

Grain has been stored in every conceivable type of container including cardboard boxes, drums, barrels, bags, coffin boxes, wooden bins, metal bins, and concrete bins. Grain is often poured on the floor without any confining container. Storage facilities that are not tight are an open invitation to birds, chickens, rodents, and insects (fig. 18). Unless a storage bin is tight, fumigation is difficult and insect control with fumigants is poor and expensive.

Good storage bins, such as the ones shown in figure 19, contain a minimum of openings for insect entry. They will also provide protection from rain, birds, and rodents. An aerating fan may be used to keep grain in good condition. Cool, dry air forced through the grain will lower grain temperature and moisture.

Figure 18. Poor storage facility is an open invitation to insects, birds, chickens, and rodents.

Figure 19. Good storage facilities with a fan for aerating the grain.

Pre-storage Bin Treatment

All storage bins and the surrounding area should be thoroughly cleaned prior to the grain harvest. The floor, ceiling and walls should be swept clean and the collected refuse removed from the storage area. The bin should then be treated with a recommended residual insecticide at least two weeks prior to harvest (fig. 20). This allows time for insects in the bin to come into contact with the insecticide. Numerous dead insects may be seen on the floor next to wall (fig. 21) following a bin spray.

Insecticides and their dilution rates for bin treatments are shown in table 2. The spray should be applied to the point of run off on bin walls, ceiling and floor. Pay particular attention to seams, corners, and cracks where particles of grain accumulate. Figure 22 shows a bin that is ready to receive grain after being cleaned and sprayed.

Wood bins constructed inside a granary have spaces between the bin wall and studs. Grain and grain dust that accumulates between studs is difficult to remove; therefore, a thorough spraying is necessary to eliminate insects in these spaces.

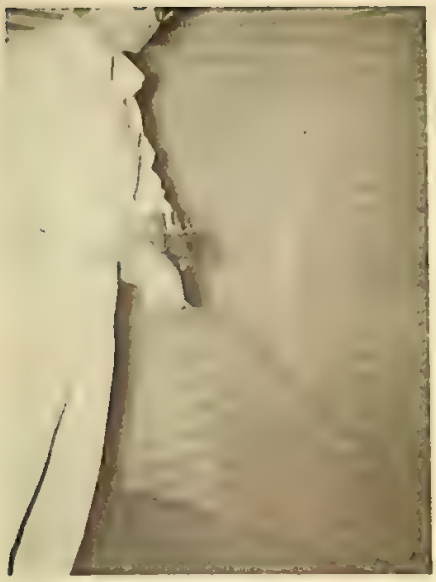

Figure 20. Pre-storage bin spraying.

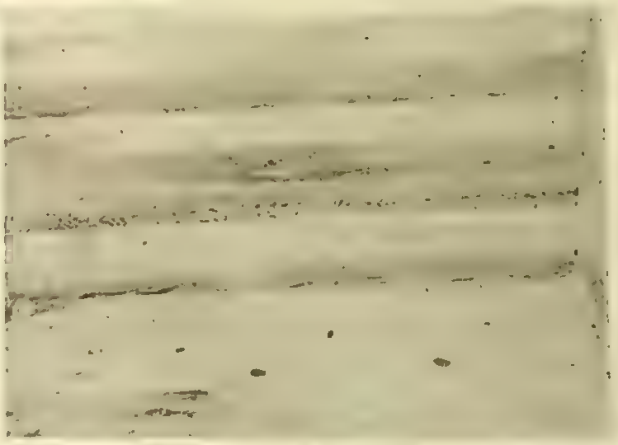

Figure 21. Dead cadelles (on the floor next to the wall) following pre-storage spray.

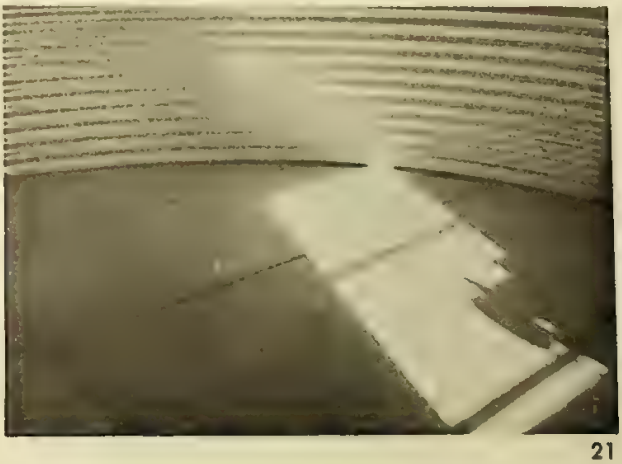

Figure 22. This cleaned and treated bin is ready to be filled with grain.

Some metal bins are equipped with air ducts. These ducts should be lifted out of place and sprayed. The bin door and ledge above the door should not be overlooked in the pre-storage bin spray. A thorough spraying of the bin is a valuable adjunct to effective protection of grain against insect damage.

Table 2. Pre-storage bin sprays and their rates of application.

Material	Quantity of material to be added to 3 gallons water	Application rate in gallons per 1,000 sq. ft. of surface
Malathion 57% E.C. (Premium grade)	1 pint	2
Methoxychlor 25% E.C.	1 quart	2
Methoxychlor 50% W.P.	1 pound	2

Pre-storage Bag Treatment

Grain is often harvested and stored in burlap bags. These bags may contain grain refuse and insects from a previous grain crop. Bags should be fumigated prior to their reuse. A large galvanized garbage can will serve as a fumigation chamber.

Malathion Grain Protectants

Many insecticides could be used to control stored grain insects except for their hazardous residues. Because of this residue problem, few insecticides have been considered for use on grain and even fewer have received approval for use by the Food and Drug Administration.

Malathion *(premium grade)* because of its effectiveness against stored grain insects and its low toxicity to humans and other warm blooded animals, has been approved for use on grain with a residue tolerance established at 8 parts per million. It has been found highly effective in protecting grain from insects for one storage season in the Middle Atlantic States.

Malathion is most effective when applied immediately after harvest to clean, dry grain. Only malathion labeled *"premium grade"* should be used on grain. The regular field grade of malathion leaves a stronger and longer lasting odor and *should not be used.* The odor from premium grade malathion is less and disappears more rapidly.

Malathion may be applied as a spray or dust at the rates shown in tables 3 and 4. Malathion used as a grain protectant controls insects present at time of application and continues to protect the grain for several months or one storage season after treatment. A decided advantage of malathion is that tight storage facilities are not necessary for good insect control. Whenever grain handling methods and equipment permit its use, malathion will provide a safe, effective, and economical control of stored grain insects.

Table 3. Malathion (premium grade) grain protectants and their rates of application to the grain stream.

Application method	Formulations and dilution rate	Application rates per 1,000 bushels of grain[1]
Total spray	1 pint 57% E.C. premium grade mixed with 5 gallons of water	5 gallons
Dust	1% premium grade on wheat flour	60 pounds

[1]A tolerance of 8.0 parts per million of malathion residue is permitted on grain. If the suggested application rates are followed, there will be no harmful residues on grain.

Table 4. Malathion (premium grade) grain protectant applied as a surface treatment to freshly harvested, stored grain.

Application method	Formulation and dilution rate	Application rate per 100 square feet of surface area[1]
Surface spray	2 ounces 57% E. C. premium grade mixed with 2½ quarts of water.	1 quart

[1] The layer of grain receiving the surface treatment should not be fed or milled before one month after treatment.

Methods of Applying Grain Protectants

Total Grain Spray

This method involves treatment of all grain as it is being elevated or augered into the storage bin. A continuous spray is applied to a continuous stream of grain. The spray may be applied at any convenient point in the movement of grain so long as the flow of grain can be regulated. (See figs. 23, 24, 25, 26, and 27). Having a knowledge of the number of bushels of grain moved per minute or hour, a spray nozzle can be obtained that will deliver the desired quantity of spray. One pint of 57% malathion *(premium grade)* mixed with 2 to 5 gallons of water should be applied to each 1,000 bushels of grain. Less than two gallons of water does not permit adequate coverage and more than five begins to add too much moisture. The important thing is that one pint of concentrate should be used for each 1,000 bushels of grain. With the lower capacity of grain handling equipment on farms, one pint of 57% malathion *(premium grade)* mixed with 5 gallons of water is necessary to give adequate coverage of each 1,000 bushels of grain.

A 3-gallon garden-type sprayer will suffice for treatment of most farm stored grain. At elevators and mills where larger quantities of grain are stored, a power sprayer, having a tank capacity of 50 gallons, would be more practical. (See. fig. 28).

When all grain being stored in a bin has been sprayed, the grain surface should be capped over lightly with the spray. The total grain spray has provided the best protection against stored grain insects.

Fig. 23. Spraying grain as it enters the top of a metal bin.

Fig. 24. Spraying grain as it leaves the auger.

Fig. 25. Spraying grain as it flows from a grain truck.

Fig. 26. Spraying grain as it is augered from a truck and elevated into a bin.

Fig. 27. Spraying grain as it flows from the end of an elevator.

Fig. 28. Power sprayer with the spray nozzle inserted into an opening in an elevator leg.

Protective Powder or Dust

Grain may also be treated with malathion protective dust or powder. Sixty pounds of 1% malathion *(premium grade)* on wheat flour will treat 1,000 bushels of grain. The protective dust is more expensive than spray due to the cost of the flour carrier. The regular formulations of malathion dust used on crops in the field should not be used on stored grain.

Dust can be sprinkled on the grain at any convenient point in the movement of grain into the bin. For best results dust should be applied evenly to clean, dry grain.

If your combine has a grain bin or grain hopper, dust can be added to the grain in the combine bin. A measured quantity of dust should be added when the combine bin is half filled with grain and then when completely filled. A knowledge of the capacity of the combine bin is essential for adding the recommended quantity of dust. The dust is mixed with the grain by the screw conveyor on the combine and mixed again as the grain is elevated or augered into the storage bin. After the bin is filled with treated grain, the grain should be leveled and the surface capped over lightly with protective dust.

Surface Spray

When malathion is applied as a surface spray only, it is essential that the bin be clean and free of insects prior to harvest. After the bin is filled, the grain should be leveled and treated immediately. The spray should be applied lightly over the entire surface and raked into the top six inches (See fig. 29). This procedure should be repeated about three times until one quart of finished spray is used for each 100 square feet of surface area. Circular 1,000 bushel metal bins will require only 1¾ pints of finished spray.

The surface spray is not recommended for use on corn. Weevils infest corn in the field and they would be brought into storage bins at harvest. Small grains are infested in the field only by surface infesting moths.

The conditions necessary for good protection of the grain using only a surface spray are rather rigid:

1. *The spray applied only to the surface will not control insects already in the bin or scattered through the grain mass; therefore, the bin must be free of insects prior to harvest.*
2. *The bin must be insect proof below the treated top six inches of the grain.*
3. *The grain must be harvested within a few days and treated immediately. If the harvest is drawn out, insects may enter the bin before the grain surface is treated.*
4. *Once the surface is treated it should not be disturbed. This surface-treated area is only a protective barrier against insect penetration of the grain mass. If the barrier is broken, good protection can not be expected.*

Surface treatments have not been as effective as the total grain spray due to the rigid conditions necessary for successful protection against insects.

Advantages of Malathion Protective Treatments

1. One application will usually provide good protection against insects for one storage season.
2. Unlike fumigation, the bin does not have to be air tight for good results.
3. Malathion will not affect germination of grain.
4. There is no adverse effect on milling and baking qualities.
5. Its early application prevents the buildup of insects and reduces the possibility of internal and external insect contamination.
6. It is safe and inexpensive.

Figure 29. Applying a surface spray immediately after filling the bin.

Fumigation

Fumigants, when applied at recommended rates to grain stored in gas tight bins, will give good control of insects inside and outside of grain kernels. Fumigation of grain in loosely constructed bins is usually costly and results are often poor.

Many formulations of fumigants are available under a variety of trade names. Some of the more common fumigants and their rates of application are shown in table 5.

Table 5. Fumigants for farm-stored grain and their rates of application.

Fumigant	Type of Bin	Gallons per 1,000 bushels		
		Wheat Rye	Shelled Corn, Oats, Barley	Grain Sorghum
Mixture of:				
80% carbon tetrachloride	metal	2	5	6
20% carbon bisulfide[1]	wood	4	6	8
Mixture of:				
75% ethylene dichloride	metal	3	6	8
25% carbon	wood	6	8	10
Mixture of:				
5% ethylene dibromide[2]	metal	2	5	6
35% ethylene dichloride 60% carbon tetrachloride	wood	4	6	8
Mixture of.				
5% ethylene dibromide 10% ethylene dichloride	metal	3	5	7
10% carbon bisulfide 76.5% carbon tetrachloride	wood	4	6	8

[1] Carbon bisulfide is explosive when used without a fire suppressant such as carbon tetrachloride.
[2] A tolerance of 50 parts per million has been established for bromide residues. Grain treated with fumigants containing ethylene dibromide should be thoroughly aerated before feeding to laying hens.

When to Fumigate

In the Middle Atlantic States it is a good practice to fumigate grain within 6 weeks after storage unless malathion grain protectant is applied at the time of storage. Most stored grain insects require 4 to 6 weeks to complete their development from egg to adult. The application of a fumigant before 6 weeks kills the insects before they build up and before they seriously damage the grain.

Grain should be inspected regularly for possible reinfestation of insects or poor control of insects. Tight bins sometime require more than one fumigation due to insect reinfestation. Bins that are not gas tight often require more than one fumigation due to poor initial kill and possible reinfestation of insects following fumigation.

How to Fumigate

Never use less fumigant than is recommended for the grain and type of bin. For instance, if 2 gallons of a fumigant are recommended for treating 1,000 bushels of grain in a metal bin, 2 gallons are necessary to provide a lethal concentration of the gas over a period of time. If the concentration of gas is too low or escapes too rapidly, some insect species or individuals will survive.

There are several important procedures that should be followed for safe, effective fumigation:

1. Level grain before fumigating. Most fumigants are heavier than air and tend to flow downhill. If grain is not level, there will be an uneven distribution of fumigant.
2. Break up any crust on the grain surface. A crusted surface will result in poor penetration and possibly uneven distribution.
3. Apply fumigants when grain temperature is above 60°F. Volatilization of liquid fumigants is poor at low temperatures.
4. Apply fumigant as a coarse spray. A bucket type sprayer or garden type sprayer with an enlarged nozzle disc opening are very satisfactory for applying fumigants.
5. Always apply fumigant from outside the bin. *It is best to work in pairs when fumigating grain.*

CAUTION: Liquid fumigants become highly volatile gases which are poisonous to humans as well as the insects. Precautions should be taken in handling and applying fumigant. *Do not enter the bin until 24 hours after fumigation.* If many bins are to be fumigated, a full-faced gas mask is recommended. Use a black canister labeled "for organic vapors." The canister should be replaced after 30 minutes exposure to organic vapors.

Grain Inspection

Grain should be inspected at least every month regardless of method used to control insects. Serious infestations are easy to detect by the numerous insects, powdered condition of grain, odor of grain, or a webbed surface. Careful inspection, however, is necessary to detect insects before they cause serious damage. Standard equipment for inspection of grain includes a grain probe, a piece of canvas or eaves trough, and a screening pan. (See fig. 30).

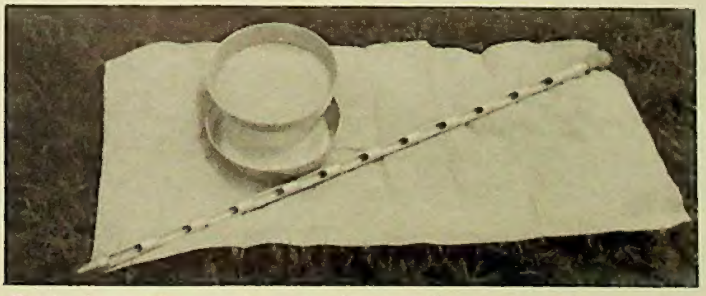

Fig. 30 Grain inspection equipment, showing the grain probe, canvas, and pans for screening the insects.

Five probe samples should be taken in different areas of the bin. They should be mixed into one composite sample from which one quart of grain is taken for careful examination. If a one quart sample contains any living weevils or lesser grain borers, or as many as 5 living bran beetles, the grain should be fumigated.

If standard grain inspection equipment is not available, improvised methods may be used to inspect grain. Always check the surface for insects and damage. Moths resting on the surface can be detected by tossing a few handfuls of grain over surface. Another inspection point is inside the bin door and around door fillers. Samples of grain should also be collected from grain shutes near bottom of the bin door. A gravel screen (8 meshes to the inch) can be used for sifting grain for insects. Insects can best be seen by sifting the grain over a white cloth or an aluminum cake pan.

Hot spots in the bin can be detected by forcing a metal rod into the grain. The hot spot and its depth from the surface can be determined by feeling the metal rod. Spot fumigation can be used if insects are the cause. If no insects are found, the grain should be turned to break up the hot spot.

Careful inspection of grain plus sanitation and chemical control of insects can often mean the difference in quality grain (fig. 31) or a total loss (fig. 32).

Fig. 31. Malathion treated grain is free of insects and damage 6 months after storage.

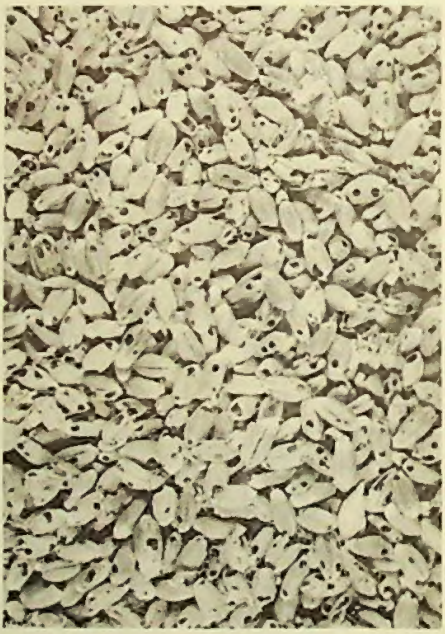

Fig. 32. This untreated grain is a total loss.

Summary of Clean Grain Practices

1. Harvest and store only grains that are dry.
2. Adjust the combine to prevent excess chaff and cracked kernels.
3. Clean the bin thoroughly before harvest.
4. Remove or fumigate old stocks of grain near the bin or in the granary.
5. Apply a recommended residual spray to the ceiling, walls and floor of the bin several weeks prior to harvest.
6. If burlap bags are to be reused, they should be fumigated.
7. Keep harvesting and grain handling equipment clean.
8. Store grain in a tight bin.
9. Treat the grain with malathion protective spray or dust as it is moved into the bin.
10. Fumigate grain within 6 weeks after harvest if malathion protectant is not used at harvest.
11. Inspect stored grain at least every month for insects, heating, and high moisture. Fumigate if grain is "weevily."
12. Aerate the grain on cool, dry days to lower the grain temperature and moisture.